

Research Report 1421

A Preliminary Evaluation of a Model Maintenance Training Program for Reserve Component Units

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Army Research Institute

AD-A173 909

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U. S. Army

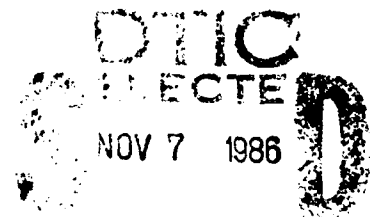
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February 1986

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARI Research Report 1421	2. GOVT ACCESSION NO. AD-A173 901	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A PRELIMINARY EVALUATION OF A MODEL MAINTENANCE TRAINING PROGRAM FOR RESERVE COMPONENT UNITS		5. TYPE OF REPORT & PERIOD COVERED Final Report January 1985 - December 1985
		6. PERFORMING ORG. REPORT NUMBER --
7. AUTHOR(s) Scott E. Graham, Theodore M. Shlechter, and Stephen L. Goldberg		8. CONTRACT OR GRANT NUMBER(s) --
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences, Steele Hall Fort Knox, KY 40121-5620		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q263743A794 512
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue, Alexandria, VA 22333-5600		12. REPORT DATE February 1986
		13. NUMBER OF PAGES 68
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) --		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE --
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) --		
18. SUPPLEMENTARY NOTES --		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		
Armor	Evaluation	Tanks
Army training	Maintenance	Training
Computer-based instruction	Maintenance training	Technical training
Computer-aided instruction	Simulation	
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)		
<p>The Model Training Program for Reserve Component Units (MTP-RC) is developing and evaluating computer-based maintenance simulation training for M1 turret and hull mechanics at the organizational and DS/GS levels. This report describes the courseware and a small-scale preliminary evaluation of the courseware's training effectiveness. Soldiers who received the simulated troubleshooting training made fewer errors per period of time on the hands-on transfer task than did control soldiers. The skills and knowledge (Continued)</p>		

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developed in the courseware also generalized to a troubleshooting task not specifically trained. Apparent success of the program is attributed, in part, to the iterative review process that paired Instructional Designers with Army Subject Matter Experts during courseware development. The resulting training program is exportable, requires a minimum of trained instructors, and trains M1 maintenance skills on equipment not physically available.

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FOREWORD

Maintenance units in the Reserve Components (RC) are facing significant training challenges as new high-technology weapons systems are introduced into the Army inventory. The Model Training Program for Reserve Component units (MTP-RC) is a joint project of the Army Research Institute and the Training and Doctrine Command's Training Technology Agency, which is attempting to produce a partial solution to the RC maintenance-training problems. The MTP-RC relies heavily on two-dimensional computer-based simulation to train soldiers to maintain the M1 tank, which may not be physically present at the reserve center or armory training site.

This report demonstrates the apparent effectiveness of the program as soldiers who received the training made fewer troubleshooting errors on hands-on performance tests than those who did not. Also included is a description of the courseware, the courseware development process, as well as a description of the potential of computer-based instruction in Army maintenance training.



EDGAR M. JOHNSON
Technical Director

A PRELIMINARY EVALUATION OF A MODEL MAINTENANCE TRAINING PROGRAM
FOR RESERVE COMPONENT UNITS

EXECUTIVE SUMMARY

Requirement:

To describe and begin evaluation of a model computer-based training program designed to train M1 tank maintenance and troubleshooting skills to Reserve Component soldiers.

Procedure:

The Model Training Program for Reserve Component Units (MTP-RC) includes approximately 200 hours of MicroTICCIT courseware developed for training M1 Turret and Hull Mechanics at the organizational and DS/GS level. Each lesson begins by describing the principles of operations of a particular system, e.g., fuel supply system. A subsequent troubleshooting segment requires the soldier to follow step-by-step the structured troubleshooting procedures in the M1 technical manuals. By using a light pen, the soldier interacts with high-resolution graphics and is able to move around in the tank, connect simulated test equipment, and receive diagnostic read-outs.

Soldiers in the training condition received 2 hours of computer-based troubleshooting training. A hands-on test required both training and control subjects to use actual test equipment to troubleshoot a modified M1 tank. Two troubleshooting procedures were evaluated, including the one trained and a similar procedure in the same system. The primary dependent measures were accuracy and speed on the hands-on tasks.

Findings:

Soldiers who received the simulated troubleshooting training made fewer errors per period of time on the hands-on tasks than did the control group. The skills and knowledge developed in the exercises not only transferred to actual equipment but generalized to a troubleshooting task that was not trained. Differences in mean GT scores between groups, however, precluded unconfounded conclusions about training effectiveness. While the courseware was designed for sustainment training, the results suggest the courseware can also be used as effective initial training.

An error analysis showed that steps requiring Breakout Box connections were frequently failed. Courseware modifications have subsequently been made to make training on Breakout Box connections more detailed and rigorous. The results also suggest that successful troubleshooting performance primarily requires job knowledge rather than motor skills. The MTP-RC training has been designed to develop requisite knowledge for both the experienced system mechanic and the system novice.

Apparent success of the program is attributed, in part, to the iterative review process that paired skilled Instructional Designers with Army Subject Matter Experts during courseware development. The resulting training program is exportable, requires a minimum number of trained instructors, and trains M1 maintenance skills on equipment not physically available.

Utilization of Findings:

The Model Training Program provides a nonresident means for preparing Reserve Component soldiers to perform their postmobilization missions. Troop readiness is potentially enhanced at reduced training costs. A trial implementation of the MTP-RC is scheduled for mid-FY86 in RC Units in Raeford, North Carolina, Dagsborough, Delaware, and Westminster, Maryland. Discussions are underway concerning use of the training at the Ordnance School, Aberdeen Proving Ground, and the Armor School, Fort Knox.

A PRELIMINARY EVALUATION OF A MODEL MAINTENANCE TRAINING PROGRAM FOR
RESERVE COMPONENT UNITS

CONTENTS

	Page
INTRODUCTION	1
Model Training Program for Reserve Component Units (MTP-RC)	2
METHOD	4
Subjects	4
Procedure	4
RESULTS	5
Background Questionnaire.	5
GT Scores	5
Paper-and-Pencil Knowledge Tests.	6
Speed and Accuracy	6
Types of Errors	7
Training Performance	8
Courseware Evaluation Questionnaire	9
DISCUSSION	9
Transfer and Generalization	9
Initial and Sustainment Training	10
Job Knowledge and Motor Skills	10
Maintenance Errors and Training	11
MicroTICCIT and Other Delivery Systems	12
CONCLUSIONS	12
REFERENCES	15
APPENDIX A. MAJOR CBI AND MAINTENANCE CBI SYSTEMS	A1
B. MTP-RC COURSEWARE DESCRIPTION	B1
C. BACKGROUND QUESTIONNAIRE.	C1
D. PAPER-AND-PENCIL KNOWLEDGE TESTS.	D1
E. COURSEWARE EVALUATION QUESTIONNAIRE	E1
F. EVALUATION CHECKLISTS FOR HANDS-ON PERFORMANCE TESTS-FSS-5 AND FSS-15.	F1

LIST OF TABLES

Table 1.	Treatment of MTP and Control Groups.	4
2.	Mean numbers of correct steps and times for FSS-5 and FSS-15 for the MTP and control groups	6
3.	Numbers of correct troubleshooting steps per minute for the MTP and control groups	7
4.	Mean numbers of six types of errors for the MTP and control groups	8
5.	Percent of possible errors	8

INTRODUCTION

The U.S. Army is incorporating computer-based instruction (CBI) into its training system. The Armor school at Fort Knox, for example, views CBI as the most dramatic shift in its training methodology (Sullivan, 1985) and plans to deliver 15 percent of its resident training on computer-based systems. Computer-based instruction can provide quality standardized instruction on a large scale at remote sites. Considering the approximately 3/4 million Active Army troops stationed on three continents and roughly again that many reserves, the potential benefits of CBI within the Army are great.

Research on CBI training (Orlansky & String, 1979) in the military has found a median time savings of around 30 percent over conventional training approaches with no reduction in training effectiveness. While the validity of some studies included in this review have been questioned, research continues to find reduced training time with CBI (Nash, 1985). If training time is reduced with no accompanying loss in effectiveness, training costs are reduced. This is particularly true in the military where personnel receive pay and allowances while being trained. Reduced training time also allows more soldiers to be trained in situations where time is the limiting factor, such as during mobilization.

Training of maintenance skills is of critical importance. The ability of soldiers to assess and repair battlefield damage is fundamental to the success of our forces, yet maintenance performance in organizational units shows considerable room for improvement. Dressel and Shields (1979) found a 42 percent false removal rate of tank turret parts submitted for direct support maintenance over a one year period. The falsely removed items accounted for 30 percent of all downtime in the direct exchange shop. Such performance is costly and adversely affects readiness.

Armistead (1983), in an analysis of operator and organizational maintenance training, found a need for improved and standardized maintenance training. He concluded that as the result of curriculum and time constraints, the schools were not adequately preparing operators and mechanics to perform the wide range of maintenance tasks required of them. The training was being left to units, and few units had well thought-out and documented maintenance training programs. To compound the problem, virtually no maintenance or maintenance training was being conducted in the field under simulated combat conditions. He further concluded that as a result, soldiers were not understanding the criticality of maintenance as related to sustainability and survivability on the battlefield.

The majority of soldiers interviewed by Armistead stated that they wanted more classroom training, and indeed the Training and Doctrine Command (TRADOC) standard was found to be changing away from nearly exclusive hands-on training to more classroom instruction. Armistead also found a resurgence in the teaching of the theory underlying the systems maintenance. Lastly, all of the schools visited reported a reduction in the amount of self-paced instruction, or else the instruction was being closely supervised to ensure that soldiers were complying with the Program of Instruction.

MG Frederic J. Brown (1984) in a maintenance White Paper has discussed the urgent need to develop a unified and coordinated organizational maintenance structure which can adequately support the fighting of a Close Combat Heavy Force. He stressed that the performance of maintenance must be

structured, done with precision, and that this required strict adherence to repair procedures delineated in verified technical manuals (TM). The Skill Performance Aids (SPA) format of the current TM describes the necessary procedures and provides supplementary illustrations for all organizational tasks. Troubleshooting procedures based on documented symptoms are described in a logic-flow pattern which isolates the fault.

One of the biggest problems in Army maintenance is that operators and mechanics both do not and cannot follow the TMs. The reasons include the number and reading level of the manuals, as well as soldiers' motivation and perceptions. Some soldiers think that good mechanics should not need to follow the step-by-step instructions or that using the TMs and special test equipment is unnecessary. This is rarely the case when one is troubleshooting a million dollar computerized system. The soldier must learn that successful maintenance performance requires the use of TMs, and the units should provide incentives for soldiers who do so (Michalak & Yager, 1979).

The Army is taking a multi-faceted approach to solve these deficiencies in maintenance training. Renewed attention is, for example, being placed on task, i.e., front-end, analyses. Efforts are also being made to improve selection and proficiency measurements. In addition, new training approaches are being explored including CBI. No one expects any single approach to solve all of the proficiency problems, but if the approaches are pursued together, significant advances can be achieved.

Computer-based instruction has the potential to address many of the specific problems found in maintenance training. Reduced training time which typically results from CBI could allow more maintenance issues to be covered within existing time constraints. Soldiers could also be trained to standardized levels of performance across various units. CBI can teach theory, in addition to procedural steps, and this instruction can readily be paired with simulated hand-on experience. Lessons on troubleshooting can require the student to carefully follow procedural steps found in TMs, and at the same time explain why the steps are being performed. Lastly, CBI reduces the reliance on Actual Equipment Trainers (AET) which can be expensive, dangerous to work on, and scarce, e.g., the M1 tank. Appendix A discusses the development of major CBI systems and reviews maintenance CBI training.

Model Training Program for Reserve Component Units (MTP-RC)

ARI and TRADOC are investigating possible CBI solutions to M1 maintenance problems for reserve component (RC) units. RC units are typically limited to 39 training days per year, split between a 2-week summer camp and monthly drills. These units are also frequently short of trained cadre and training equipment. For example, a reserve maintenance battalion which under the CAPSTONE Program would round out a division with M1 tanks has little access to M1 tanks for training. This predicates a strong argument for simulated M1 maintenance training. Also, given the distributed nature of the monthly weekend training, a CBI system which monitors progress and directs training is desirable.

Scientific Systems, Inc., Cambridge, Massachusetts, has been contracted to produce approximately 200 hours of MicroTICCIT courseware for training four Military Occupational Specialties (MOS). The courseware primarily

teaches skill level 2 maintenance tasks for turret and hull mechanics at the organizational and direct support/general support (DS/GS) level. The lessons teach the principles of operations as well as how to troubleshoot various tank systems.

The MTP-RC has been designed to train RC units to maintain equipment systems which are not physically available. The program helps ensure that soldiers have the fundamental skills to use the TMs by including both remedial instruction and repeated practice in using the TM to troubleshoot simulated equipment. A description of the courseware and courseware development process is in Appendix B.

The primary objective of the courseware is to train soldiers to use the TMs to troubleshoot simulated M1 tank systems. To this end, most of the MTP-RC courseware consists of troubleshooting segments. Each troubleshooting lesson begins by introducing a particular symptom within the system being trained. The introduction includes a conceptual explanation of what system components are possibly causing the fault. The troubleshooting lesson then presents a "Guided Demonstration" for troubleshooting that symptom in which each procedural step from the TM is cued on the screen. Two "practical exercises" follow for the same symptom, each terminating in a different fault. For example for Fuel Supply System fault #5 (FSS-5), "Fuel tank reads zero in all fuel tank selector switch positions," one exercise branches to find a faulty Hull Networks Box while another identifies the Driver's Instrument Panel.

The MicroTICCIT courseware requires the student to read the TM while troubleshooting. By using the lightpen, the soldier interacts with high resolution color graphics and is able to move around in the tank, connect simulated test equipment, and receive diagnostic readouts. Action "icons" or graphics at the bottom of the screen permit the student to connect, disconnect, inspect, remove, or replace parts and equipment.

If the student reads, "Connect red multimeter lead to point 16 on the breakout box," the student would first touch the "connect" icon and then the red lead. The screen would show, "Connect red lead to what?". The student would touch the appropriate point on the breakout box and the graphic would change to show the connection had been made. The soldier is given feedback after each step. When an error is made, information is presented in red and the correct step is identified with a green graphic overlay.

The value of any training program is determined by how well training objectives are achieved with the primary objective of the MTP-RC being to train soldiers to troubleshoot M1 tanks. The present experiment presented courseware which trains troubleshooting of Fuel Supply System fault #5. The achievement of objectives were evaluated by measuring hands-on troubleshooting performance of the fault trained and a similar fault within the same tank system. In addition, soldiers' attitudes and perceptions of the training were assessed.

METHOD

Subjects

The subjects were 16 63E soldiers enrolled in Advanced Individual Training (AIT) at Fort Knox. Each had completed training on the fuel supply system and demonstrated some Skill Level 1 maintenance proficiency on an M1 tank. The subjects were randomly assigned to two groups of eight each.

Procedure

One of the two groups was designated "MTP," (Model Training Program) and the other "Control" (no training). Table 1 summarizes the experimental procedures and sequence for the MTP and control groups.

Table 1

Treatment of MTP and Control groups

	<u>Control</u>	<u>MTP</u>
1. Background questionnaire	X	X
2. Principles of fuel system paper-and-pencil knowledge test	X	X
3. Troubleshooting training (FSS-5)		X
4. FSS-5 troubleshooting paper-and-pencil knowledge test	X	X
5. Courseware evaluation questionnaire		X
6. Hands on transfer (FSS-5) test	X	X
7. Hands-on generalization (FSS-15) test	X	X
8. Debriefing	X	X

Appendix C contains the background questionnaire which was administered to gain information about military, educational and computer experience. The soldiers' GT (General Technical) scores also were obtained, as these scores have been shown to correlate with reading ability and general intellectual ability. Appendix D contains the two multiple-choice paper-and-pencil tests assessing knowledge of fuel system principles and information presented in

troubleshooting segments. For the troubleshooting test, the soldiers were given the appropriate TMs. A Courseware evaluation questionnaire was presented to the MTP group and is included as appendix E.

As can be seen in Table 1, the primary difference between treatment groups was that soldiers in the MTP group received approximately two hours of troubleshooting training. The CBI began with an introduction to MTP-RC troubleshooting on MicroTICCIT and an overview of FSS-5. The "Guided Demonstration" in which correct responses were cued was then presented followed by three Practical Exercises. The first practical exercise was the same as the third, with the presentation order of practical exercises one and two counterbalanced. Subjects were run individually at terminals with their performance monitored by experimenters who sat behind them.

In the afternoon or following morning, the soldiers were taken to a maintenance bay which housed a modified M1 tank and were given a TM, a breakout box with cables, and a Simpson Digital Multimeter. The hands-on tests required soldiers to use the test equipment to troubleshoot the modified tank which had the driver's station broken out for easier access to cables and which is routinely used for training and evaluation by the Armor school's Maintenance Department. Two troubleshooting procedures were evaluated including the one trained (FSS-5) and a similar procedure in the same system, Fuel Supply System fault #15 (FSS-15), "Fuel gage does not show correct fuel levels". The transfer test (FSS-5) required 50 procedural steps while the generalization test (FSS-15) required 43 steps. The evaluator checklists are included as Appendix F. The order of the hands-on tests were counterbalanced. Number of correct steps and time were the major dependent measures. Each step was evaluated Go/No Go by a trained experimenter from the Maintenance Department who was blind to the treatment condition of the subject. The hands-on testing took a total of around two hours.

RESULTS

Background Questionnaire

The background questionnaire indicated that all but one of the subjects had a high school diploma. None of the subjects had much computer experience, either as part of training or otherwise.

GT Scores

An analysis of GT scores showed, that despite random assignment to treatment groups, subjects in the MTP group had a higher mean GT score (115.8) than those in the control group (103.1). That difference is statistically significant [$t(14) = 3.36$, $p < .01$]. GT score was not, however, significantly correlated with hands-on performance, $r = .37$, n.s., nor with any other performance variable. This lack of correlation suggests that performance on the criterion measures did not differ as a function of the GT range found in the sample. Nevertheless, the GT differences between the MTP and Control groups preclude any unconfounded conclusions about performance differences between training conditions.

Paper-and-Pencil Knowledge Tests

The principles of the fuel supply system test yielded no difference between the MTP and Control groups, nor were the test scores correlated with GT score. This suggests that there was no difference in the amount of job knowledge between groups before training, and that the amount of job knowledge was not related to GT scores.

Speed and Accuracy

Table 2 shows the mean number of correct steps and troubleshooting times for the two groups. Here it can be seen that soldiers who received the simulated troubleshooting training made fewer errors on the hands-on tasks than did the control group

Table 2

Mean numbers of correct steps and times for
FSS-5 and FSS-15 for the MTP and Control groups

	<u>FSS-5</u>			<u>FSS-15</u>		
	No. of Steps	(Percent)	Time (min)	No. of Steps	(Percent)	Time (min)
MTP (n = 8)	48.0	(96)	27.8	40.5	(94)	30.0
Control (n = 8)	41.9	(84)	36.6	33.9	(79)	36.9

An Analysis of Variance (ANOVA) shows soldiers who received training performed significantly more correct steps on FSS-15 than did the control soldiers; $F(1,14) = 7.13, p < .05$. A separate ANOVA yielded a marginally significant advantage for the training condition on FSS-5 as well; $F(1,14) = 4.30, p < .06$. The difference between troubleshooting times for the two groups was not statistically significant.

An efficiency measure was computed by dividing the number of correct steps performed by the amount of time taken for the two hands-on tasks. The number of correct procedural steps per minute for the two groups are shown in Table 3.

Separate ANOVAs showed statistically significant advantage for the MTP condition in troubleshooting both FSS-5; $F(1,14) = 4.76, p < .05$, and FSS-15; $F(1,14) = 4.98, p < .05$. These analyses suggest that the advantage in accuracy found for the MTP condition was not obtained at the expense of speed.

Table 3

Numbers of correct troubleshooting steps
per minute for the MTP and Control groups

	<u>FSS-5</u>	<u>FSS-15</u>
MTP	1.8	1.4
Control	1.3	1.0

Types of Errors

The troubleshooting steps for FSS-5 and FSS-15 (50 and 43 respectively) were sorted into six categories. The categories were:

1. Prepare tank/perform hull initial test conditions, e.g., set laser rangefinder switch to SAFE.
2. Multimeter set-up, e.g., set AD/DC pushbutton to DC.
3. Cable/Adaptor, e.g., connect adapter No. 2-P1 to TJ2 on hull networks box.
4. Breakout box connections, e.g., connect black test probe to test point 9 on breakout box.
5. TM procedures, e.g., turn vehicle master power ON.
6. Safety, e.g., remove all metal from neck and hands.

Table 4 shows the mean number of each of the six kinds of errors for the MTP and control groups. The total number of possible errors, and the results of separate ANOVAs are also shown. The data have been combined for both hands-on tasks, i.e., FSS-5 and FSS-15.

The training significantly reduced the number of Cable/Adaptor and Multimeter set-up errors. Training and performance with the multimeter are of particular interest since the courseware was the soldiers' initial exposure to the Simpson Digital Multimeter. Examining hands-on Multimeter set-up errors by first hands-on task and second hands-on task shows the training condition averaged .4 and .1 errors (out of six steps), while the control condition averaged 1.25 and 1.15 errors respectively.

The percents of total possible errors of each type are shown in Table 5. The data have been combined for the two groups, since we are interested in errors in general, and not specifically the results of training.

Table 4

Mean numbers of six types of errors for the MTP and Control groups

	<u>Tank Prep</u>	<u>Multimeter Set-up</u>	<u>Cable/ Adaptor</u>	<u>Breakout Box</u>	<u>TM Proc</u>	<u>Safety</u>
MTP	0.0	.5	1.0	2.2	.1	.6
Control	2.8	2.4	5.0	4.8	1.9	.5
n	(30)	(12)	(20)	(14)	(15)	(2)
F (1,14) =	1.98	4.70	19.47	2.15	4.32	.22
p <	.18	.05	.01	.17	.09	ns

Table 5

Percent of possible errors

	<u>Tank Prep</u>	<u>Multimeter Set-up</u>	<u>Cable/ Adaptor</u>	<u>Breakout Box</u>	<u>TM Proc</u>	<u>Safety</u>
Combined (n = 16)	5%	12%	15%	25%	7%	28%
Groups						

A repeated measures ANOVA indicates statistically significant differences among the frequencies of making different kinds of errors; $F(5,11) = 10.02$, $p < .001$. These data corroborate the report of the 63E course instructor who assisted the research. He indicated that the most frequent fuel supply troubleshooting errors involved inappropriate testing with the breakout box.

Training Performance

Recall that the courseware presented three troubleshooting practical exercises with the first and third being identical. Since one practical exercise required 136 MicroTICCIT interactions and the other 161, practical exercise scores were converted into percent correct to make them comparable. The mean percent of correct MicroTICCIT interactions for the first practical exercise was 88.5; the second, 92.3; and the third 95.9. Since one soldier did not finish the third practical exercise, these means are based on seven.

A correlated t-test between performance on the first practical exercise and the third (a repeat of the first) demonstrated a significant improvement

in performance $t(6) = 2.79, p < .05$. These data show that soldiers were getting better at the simulated MicroTICCIT troubleshooting with repeated practice.

Courseware Evaluation Questionnaire

The questionnaire administered immediately after the training had soldiers rate the courseware on a series of five point scales. The modal responses indicated that:

1. The guided demonstration was easy to follow.
2. The practical exercises enhanced their learning.
3. The graphics were realistic and easy to understand.
4. The troubleshooting lesson was about the right length.
5. The soldiers were confident they could do the actual troubleshooting after completing the training.
6. The computer experience was somewhat enjoyable, and more enjoyable than learning the material in the traditional classroom.

A similar debriefing questionnaire was given after completion of the two hands-on troubleshooting tasks. The soldiers' modal responses suggested that:

1. The troubleshooting exercises enhanced the soldiers' ability to do both tasks on the tank.
2. The troubleshooting exercises enhanced the soldiers' ability to follow the technical manual.
3. The troubleshooting exercises were about the same degree of difficulty as the actual troubleshooting.

DISCUSSION

Transfer and Generalization

The results indicate that the skills and knowledge developed in the simulated troubleshooting exercises do transfer to hands-on performance on the tank. The maintenance skills and knowledges also generalized to troubleshooting a task not specifically trained. On both the transfer and generalization tasks, soldiers who received training successfully completed more procedural steps per period of time than did control soldiers. As stated earlier, these findings are, however, confounded by mean GT differences between the treatment groups.

Greater accuracy for the training group on the generalization task (FSS-15) suggests the courseware is training the process of using TMs to troubleshoot, rather than training specific procedural steps. Given that schools and units do not have time to train every MOS required task, effective training should generalize to similar procedures.

The effectiveness of many training programs is jeopardized by continuing changes in equipment and procedures, in that recently trained procedures may soon become obsolete. If, as suggested, the courseware is training the process of correctly using the TM, changes in TMs are minimally expected to reduce training effectiveness. The TM skills being developed should generalize to procedural modifications and TM updates. Other training programs which, by contrast, require the use of specific job aids are more subject to update problems as procedures and equipment change. A goal of all training development should be to make the training as unaffected by TM changes as possible.

Initial and Sustainment Training

The MTP-RC courseware is being developed for sustainment training. The present research subjects were completing skill level 1 Advanced Individual Training (AIT) and a skill level 2 task was trained. In addition, the courseware used in this study also gave the soldiers their first exposure to the Simpson digital multimeter. The analysis of multimeter errors as well as the overall results suggest the courseware, although intended for sustainment training, does provide effective initial training. If additional evaluation confirms this initial training effectiveness, the potential MTP-RC applications are broadened to include use in the schools and as part of transition training.

Soldiers receiving training should ideally continue to improve following initial hands-on experience, particularly for initial training. The knowledge gained should be even more helpful after the soldier has worked with the actual equipment. The data on multimeter errors for the first and second hands-on tasks are in this direction, but given the limited performance samples are not conclusive.

Job Knowledge and Motor Skills

Successful troubleshooting performance requires both procedural job knowledge and the motor skills to implement the procedures. While MicroTICCIT interactions require some motor manipulations with the light pen, the training is essentially developing job knowledge: the name and location of tank parts, and how to use the TM. Diagnosing the underlying cause of performance errors can be difficult, for example, the errors in connecting cables and adaptors to the breakout box. While these "Cable/Adaptor" errors may seem to have a large motor component, the advantage for the training condition suggests the contrary; successful performance is principally knowledge based. The majority of current maintenance and troubleshooting tasks, e.g., electronic troubleshooting, may likewise primarily require job knowledge.

The distinction between job knowledge and motor skill requirements is essential for developing good training and evaluation. A general tendency exists to overestimate the motor skill components of many Army tasks, especially maintenance and combat tasks. This overestimation has been reinforced by the emphasis on hands-on training, performance, and evaluation. The argument is made that the "hands-on" approach is necessary because knowing "how to" do a task is different from actually being able to perform the task. This latter point is undoubtedly true, but the knowledge of "how to" perform a task is, nevertheless, a necessary component. Hands-on training is but one technique for developing requisite job knowledge, and may not be the most efficient, even when adequate resources are available.

The MTP-RC training develops job knowledge for both the experienced system mechanic and the system novice. As with other research on system experts, expert mechanics not only can execute proper procedures, but have high-level schema for how the system works. In an attempt to develop these "super-techs," the training discusses the interrelations of system processes along with explanations of why procedural steps are being performed. On the other hand, the novice or low aptitude mechanic is taught simply what must be performed in a given situation.

Maintenance Errors and Training

The analysis of hands-on errors showed breakout box errors occurred proportionately most often. These errors were likely due to a poor strategy for finding the appropriate crowded pins on the cable connectors. Courseware modifications have subsequently been made to make the training on breakout box connections more detailed and rigorous.

Safety errors were also frequent during testing. While the courseware contained warnings about removing jewelry, the soldiers were not actually required to do so during training. This should be required. The high frequency of safety errors in both groups suggests a need for greater consistent command emphasis within the schools and units, as safety performance is largely motivational.

Maintenance training is principally organized by task, i.e., an entire set of procedures for a given task is trained together. An alternative organization might focus on functional problem areas, both within and outside the context of particular tasks. If a training needs analysis were to show that breakout box or multimeter errors are frequent across a number of tasks, specific training might be presented for these most frequently failed procedures. In this direction, the introductory MTP-RC courseware contains segments presenting remedial training on use of the TMs, the Simpson multimeter, breakout box, and STE/M1 test sets. An ideal training package might develop knowledge in critical functional areas, build on this knowledge within the context of specific tasks, and then give practice applying this knowledge on actual equipment. The current training is, however, designed to be used in the absence of the actual equipment.

MicroTICCIT and Other Delivery Systems

The MTP-RC courseware has been written in ADAPT authoring language for delivery on MicroTICCIT systems. MicroTICCIT displays high resolution multi-color graphics very quickly as compared to other systems, e.g., PLATO. As described in Appendix B, the Principles of Operation and the 63H Maintenance Simulations also include videodisc pictures of tank parts and action video sequences with graphic overlays. These segments were not, however, used in the present research.

The clarity, diversity and speed of presentation of the graphics and videodisc pictures are quite impressive, but possibly have little to do with the quality of the training. As Moore, Nawrocki, and Simutis (1979) have shown, complexity of graphic displays is not in itself related to CBI training effectiveness. The MTP-RC graphics and video may enhance training effectiveness because the soldier is shown the location and function of parts, how difficult motor movements must be made, the relative position of equipment in the tank, and can simulate diagnostic test procedures. If these types of knowledge are required for task performance, and it can be demonstrated that the graphics help the student learn the knowledge, then the graphics are good. The training validity of these graphics, and other training devices, cannot, however, be accurately estimated by their fidelity to actual equipment or artistic appeal.

The MTP-RC is valuable in that it demonstrates instructional techniques which train soldiers the process of using TMs to troubleshoot. The instructional techniques used in the courseware and graphics might be represented on other delivery systems less elegant than MicroTICCIT. Other possible delivery configurations might include a videodisc based system in which the courseware and graphics are pressed on videodiscs. This solution would alleviate disk storage limitations encountered with the current 50 megabyte MicroTICCIT system. A modified version of the courseware might also run on the portable Hand Held Tutor (HHT) being developed by ARI. Since the HHT has no graphic capabilities, the graphics would need to be converted into hard copy booklets. Additional training validation would be required, however, if the instructional strategies demonstrated in the MTP-RC training program were modified for other delivery systems.

CONCLUSIONS

Reserve Components have the difficult training requirement of developing and sustaining wartime proficiency on high technology weapon systems not physically available. The MTP-RC includes approximately 200 hours of computer-based maintenance instruction, and the preliminary evaluation described suggests the courseware's training effectiveness. The instructional approach used in designing the courseware requires the soldier to troubleshoot simulated equipment by following exact procedures in appropriate TMs. The soldiers are thereby trained in the process of effectively using the TM. The training not only enhanced hands-on performance on the task trained, but also generalized to a similar task.

The instructional approach and courseware have not been shown to be more effective than any other training technique. What has been demonstrated once

again is that some training is better than no training, and in extension, more training is better than less training. The training medium and instructional approach may actually have little effect on training effectiveness. The Model Training Program for Reserve Component Units does provide one way of training maintenance skills. The training is exportable, requires a minimum number of trained instructors, and does not require an M1 tank. The MTP-RC, as a complement to present RC training programs, can enhance troop readiness and reduce training costs.

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APPENDIX A
MAJOR CBI AND MAINTENANCE CBI SYSTEMS

Several factors have led to the recent surge in CBI development. First, there has been a dramatic drop in the cost of computer hardware. Twenty years ago, 32K (kilobytes) of memory cost nearly \$100,000 and weighed 200 pounds. Today a 32K chip can fit in the palm of one's hand and costs only several dollars (Zemke, 1984). Secondly, easy to use technology for instructional design has only recently been made available. CBI courseware was often developed by computer programmers who may have had some feel for instruction, but not by individuals with backgrounds in instructional design. Another breakthrough for CBI has been the development of authoring languages, e.g. Adapt, Tutor, or Pilot for the writing of CBI and with them the ability to re-use a frame or authored structure. This has greatly reduced the amount of programming time needed to produce the CBI courseware.

Although CBI has been effective in various teaching situations, there have been limitations. CBI has not been particularly successful at teaching interpersonal skills. Automating the instruction of judgmental skills has similarly been difficult (Fisch & Nowell, 1982). In such cases where students are learning to discriminate between alternatives, tasks which are well documented with the objectives stated in measurable terms have been most readily trained. Another disadvantage of CBI is a limitation of flexibility in the curriculum. Courseware modifications can be made, but this requires increased cost and development time.

MAJOR CBI SYSTEMS

While there are now a variety of commercially available CBI systems, the two leading systems remain PLATO and TICCIT. PLATO for the major portion of its development history has been a main frame system, which is remotely accessed over phone lines. PLATO currently has nearly 10,000 hours of instruction that run the academic gamut from elementary to post-graduate work, including technical, industrial, scientific, military, and business courses (Meyers, 1984). In a relatively new application of the system, the computer simulates the behavior of complex systems, with the simulation programs allowing the users to manipulate a variety of interacting variables. The student gains simulated experience in areas which otherwise might be too dangerous, e.g., learning how to handle crises in a nuclear power plant, or too expensive, e.g., learning proper missile launch procedures.

TICCIT development began in the early 70's and was designed to be a local time-sharing system with up to 128 terminals (Kearsey, 1983). One of the major goals of the original TICCIT program was to produce a commercially successful CBI system. To this end the designers used inexpensive and off-the-shelf hardware whenever possible (Wilson, 1984). Probably the biggest difference between PLATO and TICCIT, however, is the instructional framework of the courseware. Primarily all of the early TICCIT lessons were broken down into small components with each containing a Rule-Example-Practice pattern. PLATO lessons were, by contrast, less structured with greater artistic emphasis.

Evaluating the success of CBI is often not clear-cut, and this is reflected in the evaluation of the PLATO and TICCIT courseware. Bunderson (1981) reports that early evaluations of PLATO showed no significant performance gains for students using the system as compared to conventional

classroom instruction. Students and teachers using the PLATO system did, however, show a positive attitude toward using the courseware, which was reflected in a high course completion rate. TICCIT, by comparison, which uses the more analytically built Rule-Example-Practice courseware, resulted in a significant performance advantage. On the other hand, student and teacher attitudes were not as positive and the completion rates were comparably lower.

This research reflects a continuing problem in courseware development. A delicate balance needs to be struck between the amount of artistic material which keeps the student motivated, and quality content material which yields performance gains. Montague, Wulfbeck, and Ellis (1983) believe that the road to improved CBI lies in the utilization of computer-based job aids for instructional designers and developers as a means of guaranteeing quality control. They describe several such job aid systems including the Instructional Quality Inventory (IQI) and the Computer Readability and Editing System (CRES).

A recent development for both PLATO and TICCIT is that they now include versions which run on microcomputers. The Micro-TICCIT system uses an IBM Personal Computer (PC) as a work station with a high speed communications link to the host microprocessor. The system readily displays computer generated text and graphic overlays, and is fully compatible with videodisc players. PLATO is converting much of its courseware to play on other vendors' home computers. Many courses are now available for under \$100.

CBI Maintenance Training

The actual success of CBI in training maintenance skills has been equivocal. Francis, Welling, and Levy (1983), for example, found no advantage for students given PLATO training as part of a HAWK radar repair course. Waldrop, White, and McDonald (1983) found that seamen enrolled in a basic electricity and electronics course who received CBI on strategic troubleshooting actually took longer and made more irrelevant steps than did a comparable control group. Why, given the general success of CBI, have these programs dealing with maintenance and troubleshooting failed?

The answer is repeated throughout the training development literature. CBI cannot be a panacea for training problems but is another instructional technique which requires the same scrutiny in development as any other training technique. Training development should begin with an assessment of instructional needs including a front-end analyses of the tasks to be trained and of the people to be trained (Goldstein, 1974). Training needs should then be translated into specific objectives which become the core of the training and which also are inherently linked to the evaluation criteria.

Well-defined training objectives are particularly critical when one is trying to train the ability to logically discriminate between alternatives. In the Francis, et al. study, the PLATO simulation training was presented in the middle of conventional training. In as much as the students rated the relevancy of the PLATO training to the actual job as neutral to slightly negative, the CBI was likely not well-integrated with course objectives. Similarly, the Waldrop, et al. study used CBI which consisted of

off-the-shelf troubleshooting courseware. While the basic "half-split" troubleshooting strategy trained in the courseware may be valuable, it must not have been linked specifically enough to the primary course material.

Huggett, Davis, and Rigney (1968) have developed a successful CBI system which is used to teach the operation and troubleshooting of a communications transceiver, AN/URC-32. In this program, the transceiver is hard-wired into the system which can insert and remove transceiver malfunctions. Practice in operating and troubleshooting the equipment is thereby coordinated with the presentation of technical information. The course material is organized in a general-to-specific order and includes a library capability which allows the student at any time to access an index of need-to-know topics. Program success was attributed to the structured troubleshooting approach and the student-computer-equipment interaction. These authors suggested that an attractive alternative to using the actual transceiver would be simulating the equipment on the computer.

Another successful demonstration of how CBI can improve electronic troubleshooting has come from the artificial intelligence laboratories at Bolt, Beranek, and Newman, Inc. (Brown, Rubenstein, & Burton, 1976). SOPHIE (i.e., SOPHisticated Instructional Environment) is an intelligent, generative instructional system which presents students circuits with faults at varying degrees of difficulty. The system has the student debug the fault by requesting any of a variety of measurements. At any point, the student can offer a hypothesis as to what could be wrong with the instrument, and the program returns an evaluation of the hypothesis in terms of the measurements which have been made.

STEAMER (Hollan, Hutchins, and Weitzman, 1984) is a large artificial intelligence system which simulates Navy ship steam propulsion systems. The operational parameters of the propulsion system are depicted primarily through gage readings. The system is built on robust mental models of the plant which simulate the myriad of casualty conditions which can and do occur. While such Artificial Intelligence systems are quite attractive from various perspectives, the resource requirements and costs are currently prohibitive for widespread training applications.

APPENDIX B
MTP-RC COURSEWARE DESCRIPTION

Courseware Development Process

The tank systems trained in the courseware were selected by the Ordnance school. From these systems, e.g., Laser Rangefinder System, ARI and the Ordnance school selected representative symptoms which were thought least likely to change and which had high field utility. A training task analysis identified the objective of each task to be the ability to successfully troubleshoot the particular symptom. A set of "enabling objectives" identified the job knowledges and skills required for each task, e.g., proper use of the multimeter.

Four instructional models were developed as the basis for the Name-Locate-Function, Input-Process-Output, Troubleshooting simulation and Maintenance simulation courseware segments. Courseware content was specified in a series of Lesson Specifications Documents. Army Subject Matter Experts (SMEs) and ARI reviewed the instructional models and Lesson Specification Documents.

Four generic courseware templates were then written which contained branching schemes and much of the ADAPT coding for the segment types. The templates permitted different segments to be produced primarily by inserting only the text. While the template development required a significant amount of time early in the project, SSI reports the templates resulted in an overall time savings of around 25%. In addition, these templates can be used in later CBI projects.

A key to the success of the program was the pairing of professional Instructional Designers (IDs) with SMEs in the development process. Based on the templates and Lesson Specification Documents, the SME/ID team wrote production specifications for the courseware. These specified what text and graphic or video displays were needed for each courseware segment. As a means of quality control, a second SME/ID team reviewed each production specification.

Actual courseware production was performed by a Courseware Developer, who wrote the ADAPT code and input the text, and a Graphics Specialist. Following initial debugging, the courseware was reviewed by both the original and second SME/ID teams, and sent back to the Courseware Developer for corrections.

The segment was then sent to the Ordnance school where it was reviewed for technical accuracy by SMEs and instructional approach by an Education Specialist. Special attention was paid to details of Army dress and SOPs. Review comments were returned to SSI where the SME/ID team wrote revision specifications. The modifications were made by the Courseware Developer and Graphics Specialist before final reviews.

An additional formative evaluation of the courseware has been conducted with pilot soldiers to identify problems not surfaced in the development reviews, e.g., inappropriate reading level of the text. Additional courseware modifications will be made prior to the final delivery.

The iterative review process, while costly and time consuming, may be necessary to guarantee quality in the final product. There is currently a

big push in the CBI industry to develop courseware authoring systems which can be used with little instructional design or computer experience. The training value of courseware resulting from these "easy-to-use" approaches is, however, suspect. This is not to say that courseware authoring systems are not expected to become easier to use over time, but that training of complex skills requires appropriate expertise. The success of the MTP-RC is predicated on a thorough front-end training analysis, and the pairing of skilled Instructional Designers with appropriate Army SMEs.

Introductory Courseware

Each MOS course begins with an introductory set of lessons which trains the soldier how to use the MTP-RC training program on MicroTICCIT. The courseware is designed such that once the soldier is logged onto the system, all interactions are done with a light pen, i.e., without the keyboard. The student can then receive refresher training on using the Simpson Digital Multimeter, the breakout box, and the STE-M1 test sets. Also included is a review of how to use the technical manuals with practice exercises.

The course introductions include a 20 minute M1 safety segment on video-disc developed by General Dynamics. Throughout the courseware, safety/warnings are presented whenever improper performance of a procedural step might endanger the soldier, e.g., performing a voltage test, or damage the equipment.

Principles of Operations

Each unit begins with a lesson that describes the principles of a particular system, e.g., the fuel supply system. The first segment describes the Name, Location, and Function of each part within that system. A second segment discusses the Input, Process, and Output of these same components. This basic structure is repeated in each "principles of operations" lessons.

Given the RC weekend training schedule, a uniform courseware structure should help students remain familiar with the lesson structure from month to month. This familiarity should result in reduced training time.

The contents of a typical Name-Locate-Function segment are as follows:

- Introduction
- Systems Overview
- Parts Definition
- Practice
- Review

The labels change color to indicate their status, e.g., yellow indicates a section is available to the student but has not been completed.

The Principles of Operation courseware incorporates various instructional principles including many of the cognitive factors discussed by Gagne (1970). The Introduction and System Overview specify learning objectives and newly presented information is linked to what was previously trained. In the

parts definition section, the student selects the order of discussion, as compared to a passive presentation of the information.

The training also emphasizes the use of visualization. Students must, for example, learn functional wiring diagrams. Throughout the Principles of Operation segments, video disc stills of actual tank parts and video action sequences are integrated into the courseware. These pictures are highlighted with video production shading techniques and graphic overlays. A cost-effectiveness comparison of these techniques will be completed later as part of a complete cost model.

Each Name-Locate-Function and Input-Process-Output segment includes a practice section which must be completed before the student can move to the corresponding troubleshooting lesson. The majority of the practice tests include both multiple choice and spatial relations questions involving flow charts and functional wiring diagrams. Immediate feedback is presented following each response. When an incorrect response is made, the correct alternative is highlighted with a green overlay and must be touched before the next item is presented. The default performance criterion is 100% correct.

Troubleshooting Segments

Each troubleshooting lesson begins with an introduction to a particular fault symptom in which system components that could be causing the fault are identified. The soldier is then required to troubleshoot the simulated fault by following word-for-word the procedures in the TM. A "guided demonstration" walks the soldier through the first exercise by cueing the correct lightpen interactions. Two practical exercises follow.

The 63H courseware trains the identification and repairing of bad engine and transmission parts. Many of the interactions in the 63H maintenance simulations are with videodisc pictures rather than graphics. The soldier must, for example, remove brake pads or gear sprockets and inspect them for wear.

At any point during the troubleshooting, various types of advice are available. The soldier can get an explanation of why the current steps are being performed, and frequently a detailed wiring diagram. Other types of advice include descriptions of the icons and information on the correct TM page number and next troubleshooting step.

COURSEWARE CONTENTS

Introductory Courseware

Course Introduction

MTP-RC Introduction

Tank Familiarization-Hull and Turret

M1 Test, Measurement, and Diagnostic Equipment (TMDE) Refresher Training

Simpson Digital Multimeter and Breakout Box

STE-M1/FVS

DSESTS and Power Supply (45K only)

M1 Skills Refresher Training

Technical Manuals Review

General Safety

45E-M1 ABRAMS Tank Turret Mechanic Course

Computer Subsystem

Firing Circuits Subsystem

Vehicle/Turret Power Control System

Laser Rangefinder System

63E-M1 ABRAMS Tank Systems Mechanic Course

AGT-1500 Turbine Engine

Fuel Supply System

Power Distribution and Master Power Control Systems

Electrical Charging System

X1100-3B Transmission

45K-Tank Turret Repairer Course

Turret Commander's Control Panel

Commander's Weapon Station Power Control Unit

Turret Networks Box

Gun/Turret Drive Electrical Unit

Line of Sight Electronics Unit

Traverse Mechanism Assembly

Muzzle Reference Sensor

63H-Track Vehicle Repairer Course

Troubleshooting and Repairing:

Transmission

Brakes

Turbine Engine

APPENDIX C
BACKGROUND QUESTIONNAIRE

The purpose of this survey is to assess background information about maintenance personnel. Please be as detailed in your answers as possible and leave blank or put none for any item which you cannot answer. Thank you for your time and effort.

BIOGRAPHICAL QUESTIONNAIRE

1. Student Number _____ Grade _____ Date of Birth _____
2. Parent or Designated Unit _____.
3. Current Component: RA: ARNG: RC: (Circle one)
4. Time in Service _____ yrs _____ mos; Time in Grade _____ yrs _____ mos.
5. a. Primary MOS: _____ Time in PMOS _____ yrs _____ months.
Training in PMOS: Formal Schooling, OJT, None (Circle one).
- b. Secondary MOS _____ Time in SMOS _____ yrs _____ months.
Training in SMOS: Formal Schooling, OJT, None (Circle one).
- c. Duty MOS _____ Time in DMOS _____ yrs _____ months.
6. Have you ever been re-classified? _____ (if yes) From _____ to _____
Date _____.

7. List below all maintenance courses which you have taken in the Army, including Basic Training, and any which you are taking now (use back if necessary).

<u>Titles or Courses Description</u>	<u>Location</u>	<u>Dates</u>	
		<u>From</u> (mo, yr)	<u>To</u> (mo, yr)
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

8. List below all military experiences related to working with vehicles and/or equipment.

<u>Vehicle</u>	<u>Dates</u>	
	<u>From</u> (mo, yr)	<u>To</u> (mo, yr)
_____	_____	_____
_____	_____	_____
_____	_____	_____

9. List below your most recent hands-on experiences with armor vehicles or any related piece of equipment, including training experiences.

<u>Description of Experience</u>	<u>Vehicle</u>	<u>Date</u>
		<u>mo, yr</u>
_____	_____	_____
_____	_____	_____
_____	_____	_____

10. Educational level (circle one):

- a. Less than 12 yrs; b. High School Grad; c. GED;
d. Technical School; e. Some College (state no of yrs)____;
f. College Grad (state degree)____; g. Other (describe)_____

11. List below all civilian courses which you have had with maintenance of vehicles and/or equipment: (use back if necessary)

<u>Course Description</u>	<u>Place</u>	<u>Dates</u>	
		<u>From</u>	<u>To</u>
		(mo, yr)	(mo, yr)
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

12. List below all civilian work experiences which you have had with maintenance of vehicles and/or equipment: (use back if necessary)

<u>Description of Work</u>	<u>Dates</u>	
	<u>From</u>	<u>To</u>
	(mo, yr)	(mo, yr)
_____	_____	_____
_____	_____	_____
_____	_____	_____

13. During your leisure time, as a civilian, did you work with cars and/or other types of machinery on an average. (Circle one)

- a. More than twice a week; b. Once-twice a week;
c. More than once-twice a month; d. Once-twice a month
e. Less than once a month

14. List your hobbies: _____

15. Would you normally use computers? (Circle one)

a. More than twice a week; b. Once-twice a week

c. More than twice a month; d. Once-twice a month

e. A few times a year; d. Never

16. As detailed as possible, list below your use of computers for educa-
tional (civilian and military) and professional (civilian and military) rea-
sons. (Use back if necessary.)

<u>Description of Computer Use</u>	<u>Type of Computer</u>	<u>Dates</u>	
		<u>From</u>	<u>To</u>
		(mo, yr)	(mo, yr)
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

17. As detailed as possible, list below your use of computers for personal reasons. (Use back if necessary.)

<u>Description of Computer Use</u>	<u>Type of Computer</u>
_____	_____
_____	_____
_____	_____

APPENDIX D
PAPER-AND-PENCIL KNOWLEDGE TESTS

PRINCIPLES OF OPERATION TEST

Select the best answer.

1. The smoke generator:
 - a. creates a smoke screen for the M1 by compressing exhaust gases.
 - b. can fire salvos to the right front and left front of the tank at the same time.
 - c. sprays fuel onto hot engine ducts which vaporizes and then condenses when meeting cooler air.
 - d. feeds into a two spool gasifier which drives the externally mounted oil pump.
2. The engine fuel subsystem:
 - a. pumps fuel from the rear tank to the Electro Mechanical Fuel System where it is used by the engine.
 - b. transfers fuel from the front tanks to the rear tanks.
 - c. delivers fuel to the engine, personnel heater, and smoke generator.
 - d. consists of the front and rear tanks and fuel transfer manifold.
3. The personnel heater:
 - a. circulates air from the crew compartment through the air cleaner scavenger blower and then back to crew compartment.
 - b. serves as an auxiliary system to prevent engine overheating.
 - c. will be added to the M1E1 as part of the NBC over pressure system.
 - d. produces heat for crew and driver by igniting fuel and heating air.
4. The part which houses the solenoid valves and provides a junction for the fuel lines is the:
 - a. engine fuel control.
 - b. Q.D. coupling
 - c. fuel transfer manifold.
 - d. fuel transfer pump.

5. This part prevents fuel from going back into the fuel transfer manifold:
 - a. check valve.
 - b. fuel transfer pump.
 - c. solenoid valve,
 - d. slipring
6. This part draws fuel from the front fuel tanks to the rear fuel tanks:
 - a. fuel transfer pump.
 - b. check valve.
 - c. fuel transfer manifold.
 - d. fuel tank selector switch.
7. Fuel is transferred from the front to the rear tanks when:
 - a. fuel select switch is placed on 'rear'.
 - b. low level lamp is pushed.
 - c. rear tank is below $3/4$ full.
 - d. vehicle master power switch and low level lamp are on.
8. The sponson sensors:
 - a. indicate that fuel contains too much water.
 - b. turn off pump when rear tanks are $3/4$ full.
 - c. send signals to drivers instrument panel to light low fuel lamp.
 - d. automatically choose from which of the front fuel tanks fuel will be transferred.
9. This part opens to allow fuel to be transferred from the left or right front fuel tank to the fuel transfer pump:
 - a. fuel select switch.
 - b. fuel transfer manifold.
 - c. solenoid valves.
 - d. check valve.

10. This part indicates to the driver that the rear tank is 1/4 full or less:
 - a. engine cell sensor.
 - b. fuel gage of the DIP.
 - c. low fuel level lamp.
 - d. left rear sponson.
11. This part consists of two main tanks and two sponsons. It supplies fuel to smoke generator and the engine.
 - a. front fuel tanks.
 - b. rear fuel tanks.
 - c. right front fuel tank.
 - d. batteries.
12. This stores fuel and part of it feed fuel to the personnel heater.
 - a. engine fuel subsystem.
 - b. auxiliary support tank.
 - c. rear fuel tanks.
 - d. front fuel tanks.

TROUBLESHOOTING TEST

The following questions refer to the procedure for Troubleshooting FSS-5, "The fuel gage reads zero in all fuel tank selector switch positions."

1. Why is this fault unlikely to be caused by bad sensors?
 - a. The sensors are arranged serially, if one is bad the signal stops.
 - b. All fuel tanks are monitored by the same sensor.
 - c. There is very little chance that all sensors would go out at the same time.
 - d. The Hull Networks Box will burn out if the sensors are bad.
2. What should you primarily look out for when conducting a DC voltage test?
 - a. Fire hazard.
 - b. Hull Networks Box will explode.
 - c. Shock hazard.
 - d. Zero continuity.
3. The first step for verifying that this problem exists is to:
 - a. make sure that the fuel tanks are full.
 - b. make sure that the fuel tanks are empty.
 - c. read the fuel gage with the engine running.
 - d. drive the tank until it is out of fuel.
4. After setting up standard initial conditions, you should then check:
 - a. for loose connections on the Hull Networks Box.
 - b. for loose connections on the Driver's Master Panel.
 - c. the multimeter for continuity.
 - d. the multimeter for DC voltage.

5. If the connectors are found to be faulty,
 - a. tighten both ends of the loose connector.
 - b. replace assembly or harness that has faulty connector.
 - c. check fuel gage again in all switch positions.
 - d. continue on with troubleshooting procedure to see whether other parts are faulty.
6. In Block 7, what should connector cable 1-P1 be connected to?
 - a. Hull Networks Box.
 - b. Adapter 2-J1.
 - c. Breakout Box.
 - d. Adapter 2-P1.
7. When doing a DC voltage test on the Simpson Digital Multimeter, you must:
 - a. do a continuity check between the leads.
 - b. connect the red lead to the "com" jack.
 - c. depress the "mA" function switch.
 - d. depress the "v" function switch.
8. For the multimeter test in Block 9, to what point on the Breakout Box should the red lead be connected?
 - a. 6
 - b. 9
 - c. 16
 - d. 29
9. If at Block 9 the multimeter reads "0.00" DC volts, you should then:
 - a. perform a continuity test between test point 9 on the breakout box and contact y on 2W106-P4.
 - b. prepare multimeter for the continuity test.
 - c. disconnect 2W106-P4 from J1 on driver's instrument panel.
 - d. replace Hull Networks Box.

10. Checking for continuity between contact y on 2W106-P4 and point 9 on the Breakout Box, checks that the:
 - a. fuel gage reads empty.
 - b. fuel gage is properly grounded.
 - c. fuel gage reads full.
 - d. check valve is closed.
11. What does a meter reading of 1 indicate?
 - a. A lack of continuity.
 - b. Continuity.
 - c. 1 volt DC.
 - d. A faulty multimeter.
12. In Block 15, why are you checking for continuity in harness 2W106 between P1 and P4?
 - a. To see if connections with the Breakout Box are properly connected.
 - b. To test Hull Networks Box.
 - c. To see if there is a short that disrupts power or ground.
 - d. To verify problem is solved.
13. In Block 15, the jumper should be connected to:
 - a. contacts H and X on 2W106-P4.
 - b. contacts H and X on 2W106-P1.
 - c. contacts DD and y on 2W106-P4.
 - d. contacts DD and y on 2W106-P1.
14. In Block 15, if the multimeter reads "0.00", you should then:
 - a. go to Block 16.
 - b. go to Block 17.
 - c. verify problem is solved.
 - d. check to see if multimeter is working.

15. What should be checked at the end to verify that the problem is solved?
- a. Fuel gage reads empty in all switch positions.
 - b. Fuel gage reads full in all switch positions.
 - c. Hull Network's Box is replaced.
 - d. Driver Instrument Panel is replaced.

APPENDIX E
COURSEWARE EVALUATION QUESTIONNAIRE

Please circle the alternative which best describes your feelings about the Troubleshooting exercises.

1. The instructions were:

- a. extremely easy to understand.
- b. easy to understand.
- c. neither easy nor difficult to understand.
- d. difficult to understand.
- e. extremely difficult to understand.

2. The instructions were:

- a. extremely long.
- b. too long.
- c. about the right length.
- d. too short.
- e. extremely short.

3. I felt comfortable using the computer for these lessons:

- a. immediately after the instructions were given.
- b. after the first set of lessons.
- c. about halfway through the lessons.
- d. near the end of these lessons.
- e. I am still not comfortable with using the computer for these lessons.

4. The text for the lessons was:

- a. extremely long.
- b. too long.
- c. about the right length.
- d. too short.
- e. extremely short.

5. The graphics for these lessons were:

- a. extremely easy to understand.
- b. easy to understand.
- c. nether easy nor difficult to understand.
- d. difficult to understand.
- e. extremely difficult to understand.

6. The graphics for these lessons:

- a. greatly enhanced my learning.
- b. enhanced my learning.
- c. had little effect upon my learning.
- d. detracted from my learning.
- e. greatly detracted from my learning.

7. The graphics for these lessons were:

- a. extremely realistic.
- b. realistic.
- c. unrealistic.
- d. extremely unrealistic.

8. The light-pen was:

- a. easy to use.
- b. extremely easy to use.
- c. neither difficult nor easy to use.
- d. extremely difficult to use.
- e. difficult to use.

9. The icons were:

- a. extremely easy to use.
- b. easy to use.
- c. neither easy nor difficult to use.
- d. difficult to use.
- e. extremely difficult to use.

10. The guided demonstration was:

- a. extremely easy to follow.
- b. easy to follow.
- c. neither easy nor difficult to follow.
- d. difficult to use.
- e. extremely difficult to use.

11. The guided demonstration:

- a. greatly enhanced my learning.
- b. enhanced my learning.
- c. had little effect upon my learning.
- d. hindered my learning.
- e. greatly hindered from my learning.

12. Using the "TM" materials along with the computer was:

- a. extremely easy to do.
- b. easy to do.
- c. neither easy nor difficult to do.
- d. difficult to do.
- e. extremely difficult to do.

13. Practical Exercise I was:

- a. extremely easy.
- b. easy.
- c. neither easy nor difficult.
- d. difficult.
- e. extremely difficult.

14. Practical Exercise II was:

- a. extremely easy.
- b. easy.
- c. neither easy nor difficult.
- d. difficult.
- e. extremely difficult.

15. Practical Exercise I:

- a. greatly enhanced my learning.
- b. enhanced my learning.
- c. had little effect upon my learning.
- d. hindered my learning.
- e. greatly hindered my learning.

16. Practical Exercise II:

- a. greatly enhanced my learning.
- b. enhanced my learning.
- c. had little effect upon my learning.
- d. hindered my learning.
- e. greatly hindered my learning.

17. The Troubleshooting lesson was:

- a. much too long.
- b. too long.
- c. about the right length.
- d. too short.
- e. much too short.

18. I found this computer experience to be:

- a. extremely enjoyable.
- b. enjoyable.
- c. nether enjoyable nor bothersome.
- d. bothersome.
- e. extremely bothersome.

19. After completing these exercises, how confident are you in doing actual troubleshooting work?

- a. extremely confident.
- b. confident.
- c. neither confident nor unsure.
- d. unsure.
- e. extremely unsure.

20. This computer experience was:

- a. extremely more enjoyable than learning the materials in the classroom.
- b. more enjoyable than learning the materials in the classroom.
- c. neither more nor less enjoyable than classroom instruction.
- d. less enjoyable than learning the materials in the classroom.
- e. much less enjoyable than learning the materials in the classroom.

21a Have you had any previous experiences with instructional programs, such as the Troubleshooting (panel) Trainer Device or the TTOMT, which are similiar to the Troubleshooting lessons?

no _____

yes _____

21b If yes, then for each previous experience do the following:

What type of program was this? _____.

How did this program compare to the Troubleshooting lesson? (circle one)

- a. much more positive educational experience.
- b. more positive educational experience.
- c. neither more positive nor less positive an educational experience.
- d. more negative educational experience.
- e. much more negative educational experience.

What type of program was this? _____.

How did this program compare to the Troubleshooting lesson? (circle one)

- a. much more positive educational experience.
- b. more positive educational experience.
- c. neither more positive nor less positive an educational experience.
- d. more negative educational experience.
- e. much more negative educational experience.

What type of program was this?_____.

How did this program compare to the Troubleshooting lesson? (circle one)

- a. much more positive educational experience.
- b. more positive educational experience.
- c. neither more positive nor less positive an educational experience.
- d. more negative educational experience.
- e. much more negative educational experience.

APPENDIX F
EVALUATION CHECKLISTS FOR HANDS-ON PERFORMANCE TESTS-FSS-5 AND FSS-15

TIME STARTED _____

FSS-5

TIME STOPPED _____

TOTAL STEPS _____

EVALUATOR _____

You have just received a 2404 from your Motor Sgt to troubleshoot the fuel system on an M1 Tank, "The fuel gage reads zero in any tank selector position." Your technical manuals, necessary tools are located in the area. The Simpson multimeter will be used for this task. You will be evaluated on your performance, this information will be used for the Model Training Program for Reserve Components, and will not be held for any other purpose.

Go to TM 9-2350-255-20-1-2-1-2, Para 10-2, Fig 10-5

Fuel gage shows zero in any fuel tank selector switch position.

MIS SCORE

Prepare the tank:

1. Tank parked.
2. Parking brake set.
3. Engine shut down.
4. Vehicle master power off.
5. All fuel tanks full.

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

NOTE: Read Para 10-1

COMMENT _____

STEP #1

Go to Para 10-5, Table 10-2, 84 Manual 13-6 - Table 13-4

1. Perform hull standard initial test conditions: (Tell the student that random step has been selected.)
2. "Gunner's station" set laser rangefinder switch to safe.
3. "Loader's station" turn turret lock handle clockwise to locked position.
4. "Gunner's station" swing internal/gun travel lock by releasing quick-release pin from top. Allow it to drop down until it engages.
5. Go to "Driver's station" driver master panel.
6. Set GAS PARTIC FILTER switch to off.
7. Set SMOKE GENERATOR switch to off.
8. "Driver's Instrument Panel" set fuel selector to rear.
9. "Hull Networks Box" set all circuit breaker switches to on.

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

10. "Power Distribution Box" set all circuit breaker switches to on. _____

COMMENT _____

STEP #2

Check to see if all electrical connectors are loose.

11. Try to turn 2W106-P1 connected to J12 on hull networks box. _____

12. "DIP" check 2W106-P4 connect ot J1-on DIP. _____

NOTE: If none loose go to #7.

COMMENT _____

13. Did he go to correct step? _____

STEP #7

14. "Driver's master panel" turn off vehicle master power. _____

Connect breakout box to TJ2 on hull networks box.

15. Connect cable 1-P1 to breakout box. _____

16. Connect adapter No. 2-P1 to TJ2 on hull networks box. _____

17. Connect cable 1-P2 to adapter 2-J1. _____

COMMENT _____

STEP #8

WARNING: If you don't follow all instructions, you may be exposed to voltage when preparing multimeter below.

18. Did student remove all metal from neck and hands. _____

COMMENT _____

NOTE: Give the student instruction for the Simpson meter.

NOTE: Prepare multimeter for dc voltage test for 18 to 30V dc between test points 9(-) and 16(+) on breakout box with FUEL TANK SELECTOR switch set to rear.

SIMPSON MULTIMETER

19. Turn on multimeter. _____

20. Connect the red test lead to the V-U jack. _____

21. Connect black lead to the COM jack. _____

22. Push the "V" function switch. _____
23. Set the AC-DC pushbutton to DC. (OUT) _____
24. Push the PEAK HOLD switch. (OUT) _____
25. Push the voltage range switch. If voltage measured is unknown, begin with the 1000 volt DC range, on the (200V). _____

COMMENT _____

STEP #9

26. Connect test leads to the circuit being measured. _____
27. Connect black test probe to test point 9 on breakout box. _____
28. Connect red test probe to test point 16 on breakout box. _____
29. "Go to Driver's Instrument Panel" set fuel switch to rear. _____
30. "Driver's Master Panel" set vehicle master power to on. _____

Does the reading show 18 to 30 vdc? _____

COMMENT _____

Yes to 11 No to 10

STEPS #11, 12 & 13

31. "Driver's master panel" set master power to off. Prepare Simpson multimeter for ohms test. Test for continuity between point on BOB and contact V on 106-P4. _____
32. Disconnect 2W106-P4 - from J1 on driver's instrument panel. Ref, See Fig 10-20. _____
33. Push U on meter. _____
34. 2K Range on. _____
35. Connect black test to red test probe. _____
36. Disconnect the black and red. _____
37. Connect black test to test point 9 on BOB. _____
38. Connect red test to contact Y on P4. _____
39. Disconnect test equipment. _____

Does meter show continuity?

NO-GO to 16 Yes - GO to (14)

STEP #14 (REPLACE)

MIS SCORE

From 13 to 14

1. Driver Instrument Panel is faulty.
2. What TM?
3. On the DMP turn on master power.
4. Check fuel gage on DIP, all positions.
5. On the MPT turn veh master off.

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

STEP #15

40. Disconnect 2W106-P1 from J1-4 on HNB.
41. Connect jumper between contact H and X on 2W106-P4.
42. Test for continuity between contacts V and DD on 2W106-P4.
43. Turn on meter.
44. Connect black test to DD on P4.
45. Connect red test to Y on P4.
46. Disconnect.

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Does meter show continuity?

Yes Go to 17 No Go to 16

STEP #16 (REPLACE)

From 15 to 16.

1. Replace 2W106.
2. What TM do you use?
3. Turn on master power.
4. Check fuel in all positions on the DIP.
5. Turn off master power on DMP.

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

STEP #17

1. Connect 2W106-P4 to J1 on DIP.
2. Replace hull HNB BOX
3. What TM do you use?
4. Check to ensure tank is full.

_____	_____
_____	_____
_____	_____
_____	_____

5. Turn on master power.
6. Check fuel gage in all positions DIP.
7. Turn off master power on DMP.

_____	_____
_____	_____
_____	_____

EVALUATION # _____

TIME STARTED _____

FSS-15

TIME STOPPED _____

TOTAL STEPS _____

EVALUATOR _____

You have just received a 2404 from your Motor Sgt to troubleshoot the fuel system on an M1 Tank, "The fuel gage does not show correct fuel levels - all tanks are full." Your technical manuals and necessary tools are located in the area. The Simpson multimeter will be used for this task. You will be evaluated on your performance. This information will be used for the Model Training Program for Reserve Components, and will not be held for any other purpose.

Go to TM 9-2350-255-20-1-2-1-2, Para 10-2, Fig 10-5

FAULT: Fuel gage does not show correct fuel levels - all tanks are full.

MIS SCORE

Prepare the tank:

1. Tank parked.
2. Parking brake set.
3. Engine shut down.
4. Vehicle master power off.
5. All fuel tanks full.

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

NOTE: Read Para 10-1

COMMENT _____

STEP #1

Go to Para 10-4, Table 10-2, 84 Manual 13-6 - Table 13-4.

1. Did he go to the right block?

_____	_____
-------	-------

Perform full standard initial test conditions.

2. Gunner's station" set laser rangefinder switch to safe.
3. "Loader's station" turn turret lock handle clockwise to locked position.
4. "Gunner's station" swing internal/gun travel lock by releasing quick-release pin from top. Allow it to drop down until it engages.
5. Go to "Driver's station" driver master panel.
6. Set GAS PARTIC FILTER switch to off.
7. Set SMOKE GENERATOR switch to off.

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

- | | | |
|--|-------|-------|
| 8. "Driver's Instrument Panel" set fuel selector to rear. | _____ | _____ |
| 9. "Hull Networks Box" set all circuit breaker switches to on. | _____ | _____ |
| 10. "Power Distribution Box" set all circuit breaker switches to on. | _____ | _____ |

COMMENT _____

STEP #2

Check to see if all electrical connectors are loose, that could cause symptom FSS-15.

- | | | |
|--|-------|-------|
| 11. Try to turn 2W106-P4 connected to J1 on driver instrument panel. | _____ | _____ |
| 12. Try to turn 2W106-P1 connect to J12 on hull network box. | _____ | _____ |

NOTE: If none loose go to #7.

COMMENT _____

- | | | |
|-------------------------------------|-------|-------|
| 13. Did he go to the correct block? | _____ | _____ |
|-------------------------------------|-------|-------|

STEP #7

- | | | |
|--|-------|-------|
| 14. Turn off vehicle master power. | _____ | _____ |
| 15. Disconnect 2W106-P4 from J1 on drivers instrument panel. | _____ | _____ |
| 16. Connect cable 1-P1 to breakout box. | _____ | _____ |
| 17. Connect adapter No. 2-P1 to J1 on driver instrument panel. | _____ | _____ |
| 18. Connect cable 1-P2 to adapter 2-J1. | _____ | _____ |

COMMENT _____

STEP #8

WARNING: If you don't follow all instructions, you may be exposed to voltage when preparing multimeter below.

- | | | |
|---|-------|-------|
| 19. Did student remove all metal from neck and hands. | _____ | _____ |
|---|-------|-------|

COMMENT _____

NOTE: Give the student instruction for the Simpson meter.

NOTE: Prepare multimeter for ohms test. Test for continuity between contact Y on DIP J1 and test point 22 on breakout box.

SIMPSON MULTIMETER

- | | | |
|--|-------|-------|
| 20. Turn on multimeter. | _____ | _____ |
| 21. Connect the black test probe to contact Y on J1. | _____ | _____ |

22. Connect red test probe to test point 22 on BOB.

NOTE: Does multimeter show continuity?

No Go to #9 Yes Go to #10

COMMENT _____

STEP #10

23. Connect jumper between contact Y and Z on 2W106-P1.

24. Disconnect 2W106-P1 from J12 on hull networks box.

25. Connect black test probe to contact B on P1.

26. Connect red test probe to contact X on P1.

NOTE: Is there continuity?

COMMENT _____

Yes Go to Step 12 No Go to Step 11

STEP #12 & 13

27. Connect breakout box to TJ1 on hull networks box.

28. Disconnect adapter No. 2-P1 from TJ1 on DIP.

29. Disconnect adapter No. 2-P1 to TJ1 on HNB.

30. Connect 2W106-P1 to J12 on hull networks box.

NOTE: Test for continuity between point 9 on BOB point Y on 2W106-P4.

COMMENT _____

STEP #13

31. Connect black test to test point 9 on BOB.

32. Connect red test probe to Y on P4.

Does the reading show 18 to 30 vdc?

Yes to 15 No to 14 (84 manual)

Yes to 11 No to 10 (81 manual)

STEP #14 (REPLACE)

COMMENT _____

From 13 to 14.

1. Connect 2W106-P4 to J1 on DIP.

2. Replace hull networks box.

3. What TM do you use?

4. Turn on master power.

5. Check fuel gage on DIP, all positions.

6. Turn veh master off.

STEP #15

1. Connect 2W106-P1 to J1-2 on HNB.

2. Replace DIP.

3. What TM would you use to replace the DIP?

4. Turn on master power.

5. Check fuel in all fuel select positions.

6. Turn off vehicle master power.
